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PLAYERLOAD VARIABLES ARE SENSITIVE TO CHANGES IN DIRECTION AND NOT RELATED TO COLLISION WORKLOADS IN RUGBY LEAGUE MATCH-PLAY

Submission type: Original investigation

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ABSTRACT

Purpose: Determine: 1) how change of direction (COD) workloads influence PlayerLoad variables when controlling total distance covered, and 2) relationships among collision workloads and PlayerLoad variables during rugby league match-play. **Methods:** Participants completed 3 protocols (crossover design) consisting of 10 repetitions of a 60 m effort in 15 s. The difference between each protocol was the COD demands required to complete 1 repetition; no COD (SL), 1 x 180º COD (1COD), or 3 x 180º COD (3COD). During rugby league matches, relationships among collision workloads, tri-axial PlayerLoad (PL_{VM}), anterior-posterior + medio-lateral PlayerLoad (PL_{2D}), and PL_{VM} accumulated at locomotor velocities below 2 $m.sec^{-1}$ (i.e. PL_{SLOW}) were examined using Pearson correlations (*r*) with coefficients of determination (R^2). **Results:** Comparing 3COD to SL drills: $PL_{VM}.min^{-1}$ ($d = 1.50 \pm 0.49$, *large*, likelihood = 100%, *almost certainly*), $PL_{2D}.min^{-1}$ ($d = 1.38 \pm 0.53$, *large*, likelihood = 100%, *almost certainly*), and $PL_{SLOW}.min^{-1}$ ($d = 1.69 \pm 0.40$, *large*, likelihood = 100%, *almost certainly*) were greater. $Collisions.min^{-1}$ demonstrated a distinct (i.e. $R^2 < 0.50$) relationship from $PL_{VM}.min^{-1}$ ($R^2 = 0.30$, $r = 0.55$), and $PL_{2D}.min^{-1}$ ($R^2 = 0.37$, $r = 0.61$). Total $distance.min^1$ demonstrated a *very large* relationship with $PL_{VM}.min^{-1}$ ($R^2 = 0.62$, $r = 0.79$), and $PL_{2D}.min^{-1}$ ($R^2 = 0.57$, $r = 0.76$). **Conclusions:** PlayerLoad variables demonstrate: 1) *large* increases as COD demands intensify, 2) separate relationships from collision workloads, and 3) *moderate* to *very large* relationships with total distance during match-play. PlayerLoad variables should be used with caution to measure collision workloads in team sport.

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INTRODUCTION

Wearable accelerometers, gyroscopes and magnetometers (i.e. microtechnology) are now commonly used to measure the activity profiles of field-based team sport athletes.[1,2] Tri-axial accelerometers measure the rate of acceleration across three anatomical planes; anterior-posterior (Y-axis), mediolateral (X-axis), and vertical (Z-axis).[1-3] Tri-axial vector-magnitude PlayerLoad (PL_{VM}) is calculated as the sum of the squared instantaneous rate of change in acceleration in each of the three vectors (X-, Y- and Z-axis), which is then squared and divided by 100.[3] PlayerLoad in each individual plane can also been used by practitioners wishing to measure vertical PlayerLoad (PL_{V}) or anterior-posterior (PL_{AP}) and mediolateral (PL_{ML}) PlayerLoad in isolation and collectively as PL_{2D} (i.e. PL_{AP} + PL_{ML}).[1]

Gyroscope data and PL_{VM} have also been used as part of an algorithm designed specifically for rugby league, which can be used to quantify collision counts.[4] This algorithm is sensitive to detect 97.6% of collision events during professional rugby league match-play and the typical error associated with measuring these events is 7.8%.[4] Accurately quantifying collision workloads is an important and evolving element of monitoring programs in collision sports. Higher collision frequencies have been associated with greater team success in elite and semi-elite rugby league match-play.[5,6] Not surprisingly however, physical collisions are associated with the majority of rugby league injuries during matches.[7,8] Physical contact in game-based activities produces more upper body neuromuscular fatigue, a greater and longer lasting increase in plasma creatine kinase activity, and an increased perception of effort than game-based activities involving no contact.[9]

Johnston *et al.,*[9] demonstrated that game-based activities with contact produced higher PL_{2D} than game-based activities without contact. Furthermore, Cummins *et al.,* (2017) recently demonstrated that during positional drills, hit-up forwards experienced greater relative two-dimensional accelerometer workloads than outside backs; which may not be surprising given

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that hit-up forwards experience greater match-play collision demands than outside backs.[10] However, running velocity is largely and positively related with PL_{VM} during running circuits designed to simulate soccer match-play; $PL_{VM}.min^{-1}$ is greater during sprinting efforts than jogging and striding activities.[11] In light of the available evidence, accelerometer derived PlayerLoad variables are likely to increase with concomitant increases in any workload variable (i.e. accelerations, decelerations, changes in direction, collision events, or locomotor distance).

While the value and significance of measuring and monitoring PlayerLoad variables on an individual level has been demonstrated in soccer and Australian football,[1-3,12,13] their relevance and importance to monitoring workloads in rugby league is not as clear. Before these variables are used to inform monitoring practices in rugby league, sport scientists and conditioning coaches need an understanding of what accelerometer-derived workloads truly represent.[14] For example, during professional Australian football matches, PL_{VM} is strongly correlated (R^2 = 0.90) with total distance covered; this suggests that PL_{VM} and total distance are not distinct variables and provide the same information.[15] The strong positive relationship between PL_{VM} and total distance is possibly due to the vertical (Z-axis) component of PL_{VM}; an increase in accumulated ground reaction forces while covering greater locomotor distance will be coupled with an increase in PL_V, which is one portion of PL_{VM}. As such, PL_{2D} is provided, which hypothetically (but not undoubtedly) measures collision workloads by disregarding PlayerLoad accumulated in the vertical axis (Z-axis).[16]

Additionally, Boyd *et al.*,[2] used PL_{VM} that was accumulated at locomotor velocities below 2 m.sec^{-1} (i.e. PL_{SLOW}). These authors concluded that PL_{SLOW} was a potential measure of high-intensity activities that occur at low-velocity, such as contact and wrestling or acceleration, deceleration and change of direction movements occurring in small spaces in Australian football.[2] Indeed, during game-based training in rugby league, PL_{SLOW} increased in

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line with the amount of contact and wrestling efforts that players were required to perform.[17] However, the relationship between PL_{SLOW} and distance covered below the same velocity threshold (2 m.sec^{-1}) is yet to be established in professional rugby league players.

Although the relationships among collision workloads, PL_{VM}, and PL_{2D} have been established in semi-professional rugby league players,[10] more information may be provided by investigating: 1) collision workloads in comparison with PlayerLoad in each individual plane during professional rugby league matches, and 2) how change of direction workloads influence all PlayerLoad variables. The purpose of this investigation was two-fold. First, we aimed to determine how the addition of accelerations, decelerations and changes in direction influence PlayerLoad variables when controlling for total distance covered. Second, we aimed to examine the relationship between collision workloads and PlayerLoad in each anatomical plane during professional rugby league match-play.

METHODS

Participants

Sixteen junior rugby league players (mean ± SD; age, 16.8 ± 0.8 yr; height, 178.7 ± 4.7 cm, mass, 85.9 ± 9.0 kg) participated in the first part of this study. These players were from the development squad of a professional rugby league club. The second part of the study included 25 professional rugby league players (age, 25.6 ± 2.7 yr; height, 184.0 ± 5.0 cm, mass, 98.7 ± 8.9 kg) during 270 (10.9 ± 5.5 per player) individual appearances in Australian National Rugby League (NRL) competition. The study was approved by an ethics committee at the University of Queensland.

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Experimental design

Part one

The influence of accelerations, decelerations and changes in direction on all PlayerLoad variables when controlling for total distance covered was investigated by having each participant complete 3 separate drills in a crossover design. Each drill required participants to complete 10 repetitions of a 60 m effort in 15 s, on a 1:1 work:rest ratio (Figure 1). The difference between each drill was the number of changes in direction required to complete one repetition; drill A required no change in direction (straight line; SL), drill B required 1 x 180º change in direction (1 COD), and drill C required 3 x 180º changes in direction (3 COD). After each repetition, the participants had 15 seconds to walk a 5 m 'out-and-back shuttle' before beginning the next repetition. The distance required to complete each drill was 700 m (140 $m.min^{-1}$). The influence of change of direction workloads on acceleration and deceleration activity was assessed by counting the total number of accelerations and decelerations in each drill using global positioning system (GPS) technology that has demonstrated appropriate accuracy for measuring these variables in team sports (Catapult, Optimeye S5, firmware version 7.27, Melbourne, Australia).[18]

Each participant was randomly assigned to one of three groups and rotated through each drill during three training sessions; a minimum of seven days separated each of the testing sessions. Across the three sessions, the groups completed the drills in the following orders: group 1, drills A, B, and C; group 2, drills B, C, and A; group 3, drills C, A, and B. A standardised warm-up preceded each testing session and the participants were familiarised with the speed at which they were required to run in order to complete each repetition in the required 15 seconds. The 15 second work and recovery times were controlled by an audible signal emitted via a speaker. If participants ran at a speed that resulted in the completion of any

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repetition faster than 15 seconds, their data were removed from the analysis (n = 2). All variables were analysed relative to the duration of each drill.

Factorial analysis of variance (ANOVA) was used to identify differences in each variable between the straight line, 1 COD, and 3 COD conditions. Any significant differences were assessed with the use of Bonferroni adjusted confidence limits. Statistical significance was set at $P < .05$. As multiple comparisons were being made, a practical approach determining the scale of difference between each protocol was used. Specifically, all data were log-transformed and compared using Cohen effect-size (*d*) statistic and 90% confidence intervals (CI), which determined the magnitude of any differences.[19,20] The magnitude of the *d* was classified as *trivial* (<0.2), *small* (0.21–0.6), *moderate* (0.61–1.2), *large* (1.21–2.0), or *very large* (>2.1). In the event that the 90% CI overlapped both positive and negative thresholds the *d* was classified as *unclear*.[19,20]

Part two

The relationship between collision workloads and all PlayerLoad variables during professional rugby league match-play was examined. A total number of 12,039 collision events (481.6 ± 314.1 per player) were examined across all matches. Participants were fitted with microtechnology equipment (Catapult, Optimeye S5, firmware version 7.27, Melbourne, Australia) that has demonstrated accuracy for measuring collision counts during professional rugby league match-play,[4] and acceptable within- (CV 0.91 to 1.05%) and between-device (1.02 to 1.90%) reliability for measuring rate of change in acceleration, which is used to calculate PlayerLoad.[3] These microtechnology devices have demonstrated a capacity to identify 97.6% of collision events during rugby league match-play.[4] Low-intensity (<1 PlayerLoad AU), and short duration (<1 s) collision reports were excluded, as this improves the accuracy (92.7%) and typical error of estimate (7.8%) for these devices to detect collision

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events during matches.[4] In order for a collision to be detected by the microtechnology device, a spike in instantaneous PlayerLoad ≥2 arbitrary units (AU) is required to occur along with a change in orientation of the device (>60° forwards; >45° left or right; >30° backward), which is measured using the gyroscopes axes for yaw, pitch, and roll.[4,21]

As collision events of a duration greater than 5 seconds have been reported,[4] a measure of overall collision intensity was also investigated; the PL_{VM} accumulated during collision events (i.e. collision-PL_{VM}) was quantified. This was done by summating PL_{VM} between the commencement (i.e. initial spike in instantaneous PlayerLoad ≥2 arbitrary units [AU]) and the conclusion (i.e. return of the device to an upright position) of each collision event.[4]

All data were log-transformed to reduce non-uniformity of error. Potential relationships between the number of collisions sustained, PL_{VM} accumulated during collision events (i.e. collision-PL_{VM}), all PlayerLoad variables, total distance covered, and distance covered <2 $m.sec^{-1}$ during matches were determined using Pearson correlations (r), which were derived using the Statistical Package for Social Sciences (SPSS). The magnitude of each relationship (r) was classified as *small* (0.0-0.29), *moderate* (0.30-0.49), *large* (0.50-0.69), *very large* (0.70-0.89), *nearly perfect* (0.90-0.99), and *perfect* (1.00).[19] Coefficients of determination (R^2) were also used to interpret the meaningfulness of any relationship; an R^2 less than 0.5 (50%) indicates that two variables are distinct and independent in nature.[22]

RESULTS

Part one

The total number of accelerations and decelerations was greater in the 3 COD condition (83.0 ± 2.4), compared to 1 COD (71.1 ± 5.9; d = 1.55 ± 0.40, *large*, likelihood = 100%, *almost certainly*) and straight line conditions (40.5 ± 5.5; d = 1.90 ± 0.17, *large*, likelihood = 100%, *almost certainly*).

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$PL_{VM}.min^{-1}$ was greater during the 3 COD condition than during 1 COD (d = 0.72 ± 0.64, *moderate*, likelihood = 91%, *likely*, P = 0.005) and straight line (d = 1.50 ± 0.49, *large*, likelihood = 100%, *almost certainly*, P = 0.000) conditions (Figure 2A). During the 3 COD protocol, $PL_{2D}.min^{-1}$ was greater than the 1 COD (d = 0.91 ± 0.61, *moderate*, likelihood = 97%, *very likely*, P = 0.001), and straight line (d = 1.38 ± 0.53, *large*, likelihood = 100%, *almost certainly*, P = 0.000) protocols (Figure 2B). $PL_{ML}.min^{-1}$ was greater when completing 3 COD than 1 COD (d = 0.96 ± 0.59, *moderate*, likelihood = 98%, *very likely*, P = 0.001) and straight line running (d = 1.52 ± 0.45, *large*, likelihood = 100%, *almost certainly*, P = 0.000) protocols (Figure 2D). There was a *large* increase in $PL_{SLOW}.min^{-1}$ during the 3 COD protocol, compared with the 1 COD (d = 1.29 ± 0.54, *large*, likelihood = 100%, *almost certainly*, P = 0.000) and straight line (d = 1.69 ± 0.40, *large*, likelihood = 100%, *almost certainly*, P = 0.000) protocols (Figure 2F).

$PL_{SLOW}.min^{-1}$ (d = 0.91 ± 0.59, *moderate*, likelihood = 97%, *very likely*, P = 0.004), $PL_{ML}.min^{-1}$ (d = 0.83 ± 0.60, *moderate*, likelihood = 96%, *very likely*, P = 0.003), $PL_{V}.min^{-1}$ (d = 0.84 ± 0.60, *moderate*, likelihood = 96%, *very likely*, P = 0.006), and $PL_{VM}.min^{-1}$ (d = 0.96 ± 0.58, *moderate*, likelihood = 98%, *very likely*, P = 0.002) were greater during the 1 COD protocol than the straight line condition (Figure 2). An *unclear* difference was found between $PL_{AP}.min^{-1}$ (d = 0.11 ± 0.67, *unclear*, likelihood = 41%, *possibly*, P = 0.999) when comparing the 1 COD and straight line conditions (Figure 2C).

Part two

The relationships between measures of collision, PlayerLoad, and locomotor activity during professional rugby league match-play are displayed in Table 1. The number of $Collisions.min^{-1}$ were related with collision-$PL_{VM}.min^{-1}$ (R^2 = 0.93, r = 0.97, *nearly perfect*). $Collisions.min^{-1}$ demonstrated a distinct (i.e. R^2 <0.50) relationship from: $PL_{VM}.min^{-1}$ (R^2 =

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0.30, r = 0.55, *large*), $PL_{2D}.min^{-1}$ (R^2 = 0.37, r = 0.61, *large*), $PL_{AP}.min^{-1}$ (R^2 = 0.34, r = 0.59, *large*), $PL_{ML}.min^{-1}$ (R^2 = 0.38, r = 0.62, *large*), $PL_{V}.min^{-1}$ (R^2 = 0.20, r = 0.45, *moderate*), $PL_{SLOW}.min^{-1}$ (R^2 = 0.22, r = 0.47, *moderate*).

Total distance.min^1 demonstrated a *very large* relationship with: $PL_{VM}.min^{-1}$ (R^2 = 0.62, r = 0.79, *very large*), $PL_{2D}.min^{-1}$ (R^2 = 0.57, r = 0.76, *very large*), $PL_{AP}.min^{-1}$ (R^2 = 0.56, r = 0.73, *very large*), $PL_{ML}.min^{-1}$ (R^2 = 0.53, r = 0.73, *very large*), $PL_{V}.min^{-1}$ (R^2 = 0.62, r = 0.79, *very large*).

$PL_{SLOW}.min^{-1}$ had a distinct (i.e. R^2 <0.50) relationship from: the number of Collisions.min^{-1} (R^2 = 0.22, r = 0.47, *moderate*), Total distance.min^1 (R^2 = 0.32, r = 0.57, *large*), and Distance <2 m.sec^{-1}.min^{-1} (R^2 = 0.07, r = 0.26, *small*).

DISCUSSION

We investigated whether PlayerLoad variables are influenced by change of direction workloads, and examined the relationships among collision workloads and PlayerLoad variables during professional rugby league match-play. Our findings demonstrate that all PlayerLoad variables are sensitive to change of direction workloads. In addition, PL_{2D}, PL_{VM}, PL_{AP}, PL_{ML}, PL_{V}, and PL_{SLOW} each demonstrated a distinct relationship from collision workloads during professional rugby league matches. As such, these variables should be used with caution when quantifying the collision demands of rugby league match-play. Specifically, when compared to collision workloads, all PlayerLoad variables demonstrated an R^2 of <0.5, which suggests that the variables are separate and independent.[22] As such, although PlayerLoad provides a summation of the rate of acceleration change occurring during activity, it does not provide a valid measure of collision workload.

Total distance covered demonstrated a *very large* relationship (r > 0.70, R^2 > 0.50) with PL_{VM}, PL_{AP}, PL_{ML}, and PL_{V} during professional rugby league match-play. However, the

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magnitude of the relationship between total distance and PL_{VM} was smaller in this study than the *nearly perfect* relationships reported in Australian football (r = 0.94, R^2 = 0.90),[15] and soccer (r = 0.93, R^2 = 0.86).[23] We believe that the differences in these relationships may be due to dissimilarities in acceleration and contact demands between these sports.[24] Relative to match-play durations, rugby league players cover less total distance and complete a greater number of acceleration efforts than Australian football and soccer players.[24] Furthermore, the relationship between PL_{VM} and the number of collisions is stronger in positions where contact demands are higher during rugby league match-play.[10] Collectively, these findings demonstrate that compared with other field-based team sports, PL_{VM} provides a lower predictive value as a surrogate measure of total distance covered during rugby league match-play. Furthermore, PlayerLoad variables may be considered a better indication of ‘global’ external workload than a quantification of various movements in isolation (i.e. collision events, acceleration, deceleration or change of direction workloads).

PL_{SLOW} demonstrated the greatest sensitivity to change of direction workloads. For example, although all PlayerLoad variables demonstrated at least *moderate* effect size differences between 1 COD and 3 COD protocols, PL_{SLOW} was the only variable that demonstrated a *large* effect size difference between these conditions. Furthermore, PL_{SLOW}, which is the accumulated PL_{VM} below a locomotor velocity of 2 $m.sec^{-1}$, was not related with distance covered below the same velocity threshold (2 $m.sec^{-1}$) during match-play. This finding may be surprising given that overall total distance covered and PL_{VM} had a *very large* correlation and were not distinct variables. However, these findings collectively suggest that PL_{SLOW} may be capable of quantifying high intensity movements such as changes in direction that occur at locomotor velocities below 2 $m.sec^{-1}$. However, practitioners should consider that increases in PL_{SLOW} may be due to other activities such as contact and wrestling that occur at low movement velocities.[17]

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During rugby league matches, PL_{2D} demonstrated: 1) *nearly perfect* relationships with PL_{VM}, PL_{AP}, PL_{ML}, and PL_{V}, and 2) a distinct relationship from collision workloads. Furthermore, when controlling for total distance covered, *large* effect size differences were demonstrated between PL_{2D} during straight line and multiple change of direction efforts (3 COD). These findings indicate that PL_{2D} does not provide any additional information on collision workloads than other PlayerLoad variables. Although small-sided games with contact produced greater PL_{2D} than small-sided games without contact,[9] increases in PL_{2D} may not always be the result of collision workloads; PL_{2D} is sensitive to change in direction workloads and has a separate relationship with collision workloads during rugby league matches. Practitioners should use this variable with caution when quantifying collision workloads in team sport.

PL_{AP} revealed the weakest relationship with change of direction workloads; only *moderate* differences were found between the straight line and 3 COD conditions, whereas other PlayerLoad variables demonstrated *large* differences. This finding demonstrates that when these change of direction tasks were completed, there was a greater increase in loading in the medio-lateral and vertical planes than in the anterior-posterior plane. Considering that PL_{AP} is a component of PL_{2D}, practitioners should note that both PL_{AP} and PL_{2D} may not be as appropriate for quantifying change of direction workloads as PL_{ML}, PL_{V}, and PL_{SLOW}. Given that greater blood lactate concentration, heart rate and oxygen uptake have been demonstrated following running with change of direction requirements than straight line running,[25-27] our findings suggest that PlayerLoad variables may be capable of providing important information on the demands of training sessions or matches in team sport.

Although the present study provides novel and practically applicable findings; there a number of limitations that need to be considered. Firstly, we investigated the influence of change of direction workloads on PlayerLoad variables during three conditions that were

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standardised for total distance covered. However, we did not investigate the effect of progressive increases in collision demands across three conditions on PlayerLoad variables. This would likely have provided more information on the use of PlayerLoad to measure collision demands. However, our findings still demonstrate that: 1) *large* differences were evident in PlayerLoad variables when increases in change of direction were present, and 2) collision counts during match-play were distinct from all PlayerLoad variables. Collectively, these findings demonstrate that all PlayerLoad variables are incapable of providing accurate measures of collision workloads during rugby league match-play and cannot be used to measure contact workloads as they may be influenced by running demands.

PRACTICAL APPLICATIONS

This study provides a number of applications that have practical value to sport scientists, conditioning coaches, and researchers in team sport. We have demonstrated that all PlayerLoad variables are sensitive to change of direction workloads. During professional rugby league matches, all PlayerLoad variables demonstrated: 1) separate relationships from collision workloads, and 2) *very large* relationships with total distance covered. Furthermore, with the exception of PL_{SLOW}, all PlayerLoad variables demonstrated *nearly perfect* relationships among each other; the application of these variables does not provide an additional measure of activity profiles than PL_{VM} during rugby league match-play. As such, the application of PlayerLoad variables to measuring isolated collision workloads in team sport should be conducted with restraint. Collectively, these findings demonstrate that no PlayerLoad variable provides a valid measure of collision workload in team sport.

PL_{SLOW} demonstrated the greatest sensitivity to change of direction workloads. As such, movements such as accelerations, decelerations, and changes of direction that occur at low velocities may result in an increase in PL_{SLOW}. Additionally, PL_{SLOW} showed a distinct

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relationship from collision counts and total distance covered during rugby league matches, rendering it less useful for quantifying these parameters during competition. Furthermore, PL_{AP} was not as sensitive to change of direction workloads as PL_{ML} and PL_{V}. Practitioners endeavouring to quantifying change of direction demands should consider PL_{ML} and PL_{V} as more appropriate than PL_{AP}, and PL_{2D}.

CONCLUSIONS

This study provides information on the ability of accelerometer-derived workloads to quantify change of direction and collision workloads. We believe that this information can be used to inform the monitoring of external workloads in team sport. However, we note that the link between physiological and biomechanical measures of workload, and their associated outcomes should be considered when implementing these findings in practice.[28]

Although PL_{VM} and its associated alternatives provide an overall quantitation of the workload associated with a given training session or match, no PlayerLoad variable is capable of accurately quantifying collision events. With the exception of PL_{SLOW}, all PlayerLoad variables have a closer relationship with total distance covered than collision workloads. Indeed, these variables can be used by practitioners to quantify the volume and intensity of training sessions and matches. However, further investigation may be required if practitioners need to identify what type of movements have caused variations in any PlayerLoad variable.

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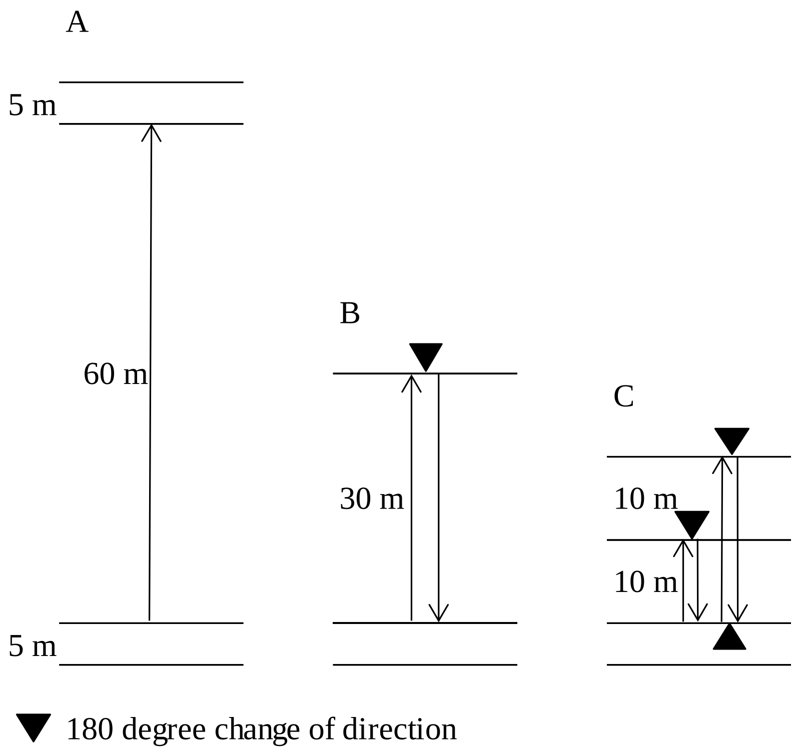

Figure 1. Design of 3 experimental protocols used to determine how the addition of changes in direction influence all PlayerLoad variables when controlling for total distance covered. One repetition of each drill involved a 60 m running effort completed in 15 seconds; drill A was a 60 m straight line effort, drill B was a 60 m shuttle run with 1 change of direction (1 COD), and drill C was a 60 m effort with 3 changes in direction (3 COD). The participants had 15 seconds to walk a 5 m ‘out-and-back’ recovery between each repetition.

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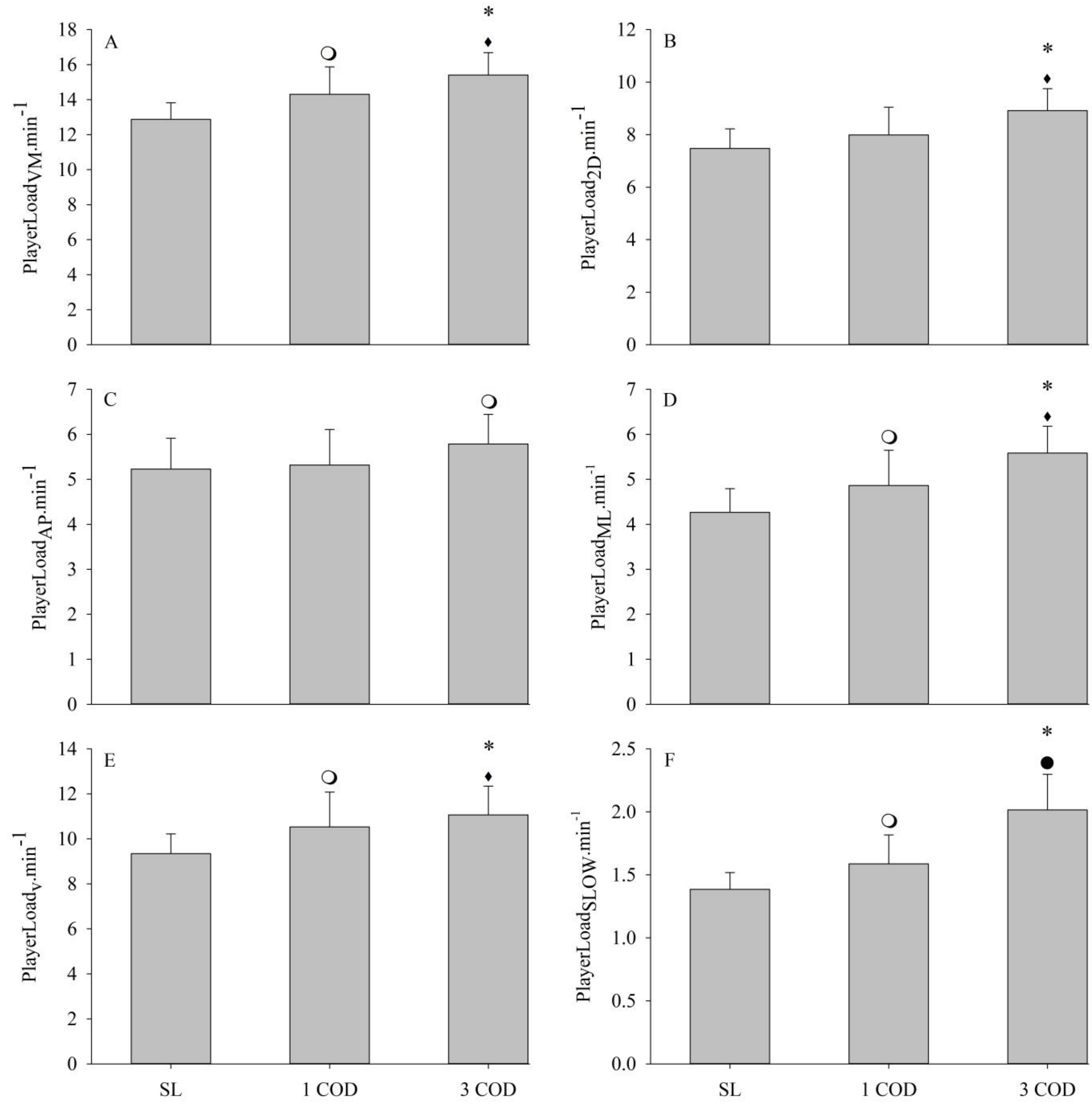

Figure 2. Differences in PlayerLoad variables when controlling for distance covered and adding change of direction tasks in junior rugby league players. Data are presented as mean ± SD.

SL = Straight line running at 140m/min; 1 COD = 140 m/min with 1 x 180º change of direction;

3 COD = 140 m/min with 3 x 180º changes of direction.

**Large* effect size difference from SL; ●*Large* effect size difference from 1 COD; ❍*Moderate* effect size difference from SL; ♦*Moderate* effect size difference from 1 COD.

"Playerload Variables are Sensitive to Changes in Direction and Not Related to Collision Workloads in Rugby League Match-Play" by Hulin BT, Gabbett TJ, Johnston RD, Jenkins DG
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Table 1. Relationships between measures of collision, PlayerLoad (PL), and locomotor activity during professional rugby league match-play.

	Collision		*PL*						*Walking & running*	
***R^2* (r)**	Collision-PL_{VM}.min^{-1}	Number of Collisions.min^{-1}	PL_{VM}.min^{-1}	PL_{2D}.min^{-1}	PL_{AP}.min^{-1}	PL_{ML}.min^{-1}	PL_{V}.min^{-1}	PL_{SLOW}.min^{-1}	Total distance.min^{-1}	Distance <2 m.sec^{-1}.min^{-1}
Collision-PL_{VM}.min^{-1}	1.00 (1.00)									
Number of Collisions.min^{-1}	0.93 (0.97)	1.00 (1.00)								
PL_{VM}.min^{-1}	0.33 (0.58)	0.30 (0.55)	1.00 (1.00)							
PL_{2D}.min^{-1}	0.40 (0.63)	0.37 (0.61)	0.96 (0.98)	1.00 (1.00)						
PL_{AP}.min^{-1}	0.35 (0.59)	0.34 (0.59)	0.91 (0.95)	0.97 (0.98)	1.00 (1.00)					
PL_{ML}.min^{-1}	0.42 (0.65)	0.38 (0.62)	0.91 (0.95)	0.93 (0.97)	0.82 (0.91)	1.00 (1.00)				
PL_{V}.min^{-1}	0.23 (0.48)	0.20 (0.45)	0.95 (0.98)	0.83 (0.91)	0.78 (0.88)	0.80 (0.89)	1.00 (1.00)			
PL_{SLOW}.min^{-1}	0.25 (0.50)	0.22 (0.47)	0.62 (0.79)	0.60 (0.77)	0.57 (0.76)	0.56 (0.75)	0.58 (0.76)	1.00 (1.00)		
Total distance.min^{-1}	0.09 (0.30)	0.09 (0.30)	0.62 (0.79)	0.57 (0.76)	0.56 (0.73)	0.53 (0.73)	0.62 (0.79)	0.32 (0.57)	1.00 (1.00)	
Distance <2 m.sec^{-1}.min^{-1}	0.09 (-0.31)	0.12 (-0.34)	0.01 (-0.12)	0.02 (-0.15)	0.02 (-0.16)	0.03 (-0.16)	0.01 (-0.08)	0.07 (0.26)	0.05 (0.23)	1.00 (1.00)

Coloured shading represents a correlation (r) that is:

Small	Moderate	Large	Very large	Nearly perfect	Perfect